Studies of the Influence of moonlight on observations with MAGIC

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DPG Frühjahrstagung München

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Motivation and Outline

MAGIC

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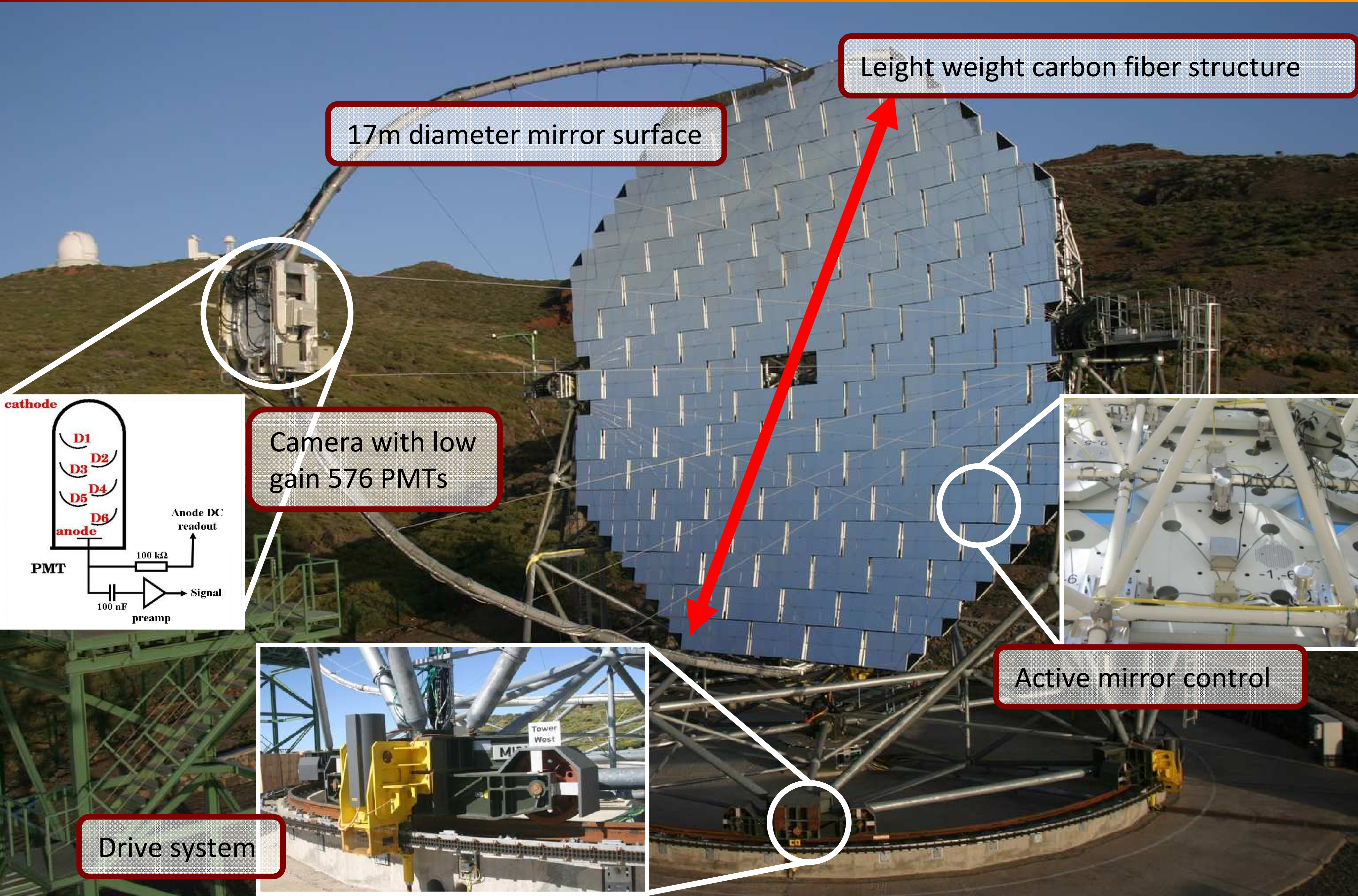
(Werner-Heisenberg-Institut)

- The MAGIC telescope
- Motivation
- Observation times
- A model to estimate the diffuse moonlight
- The Sensitivity of the MAGIC I Telescope during Moon time observations
- Summary

The MAGIC Telescope



Motivation

Motivation

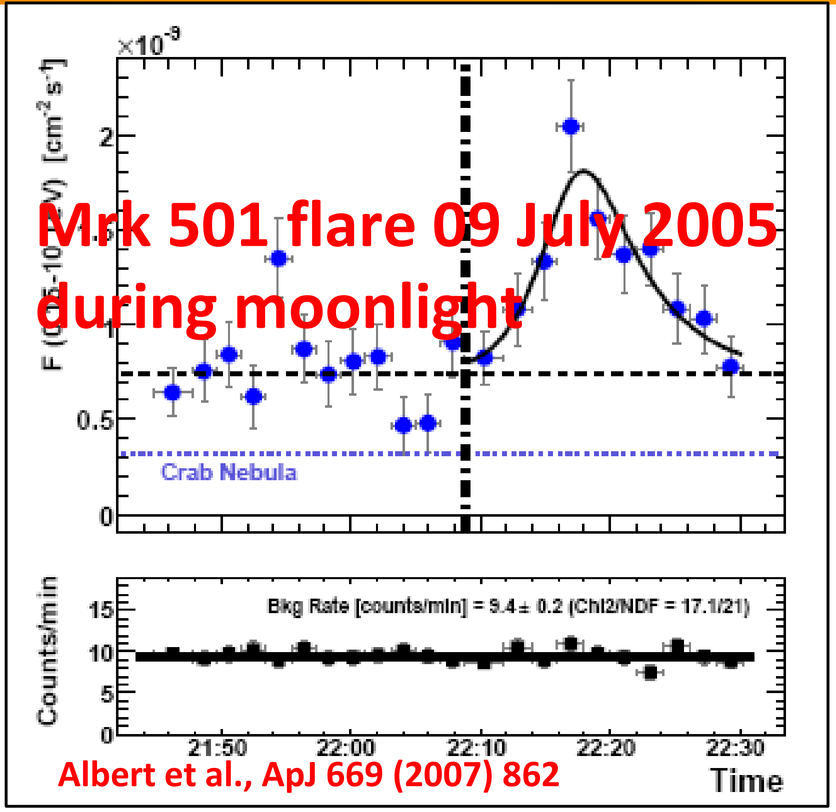
- Observation time
- Diffuse background light
- Twilight observations
- Specially designed camera (PMT gain only 3×10^4)
- Many physics results yet

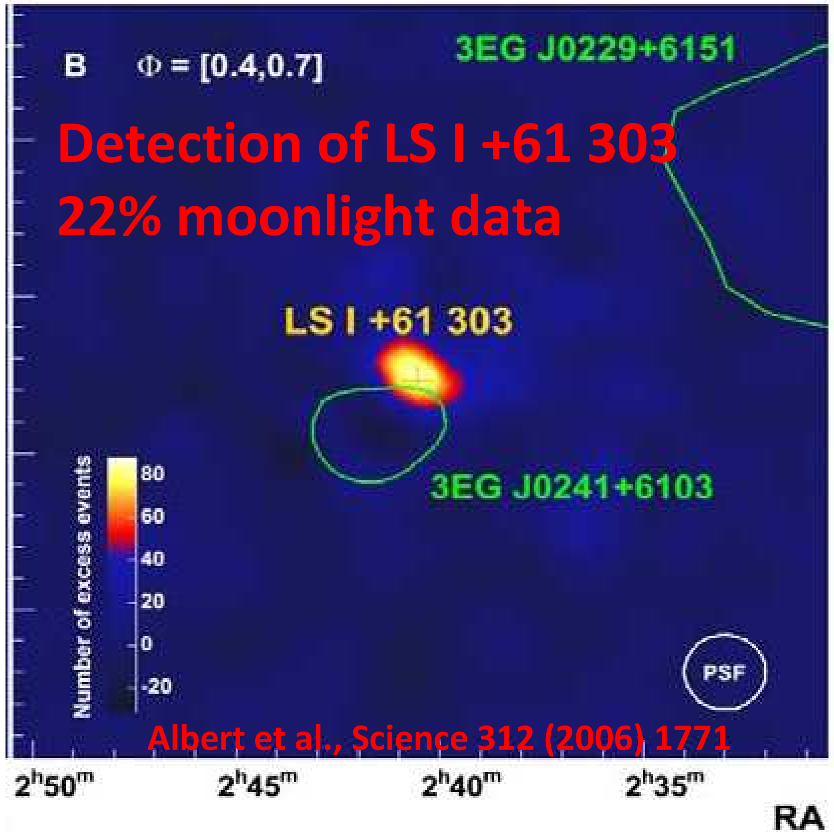
Problem

- Light showers get lost in higher background
- Offline Analysis

Task

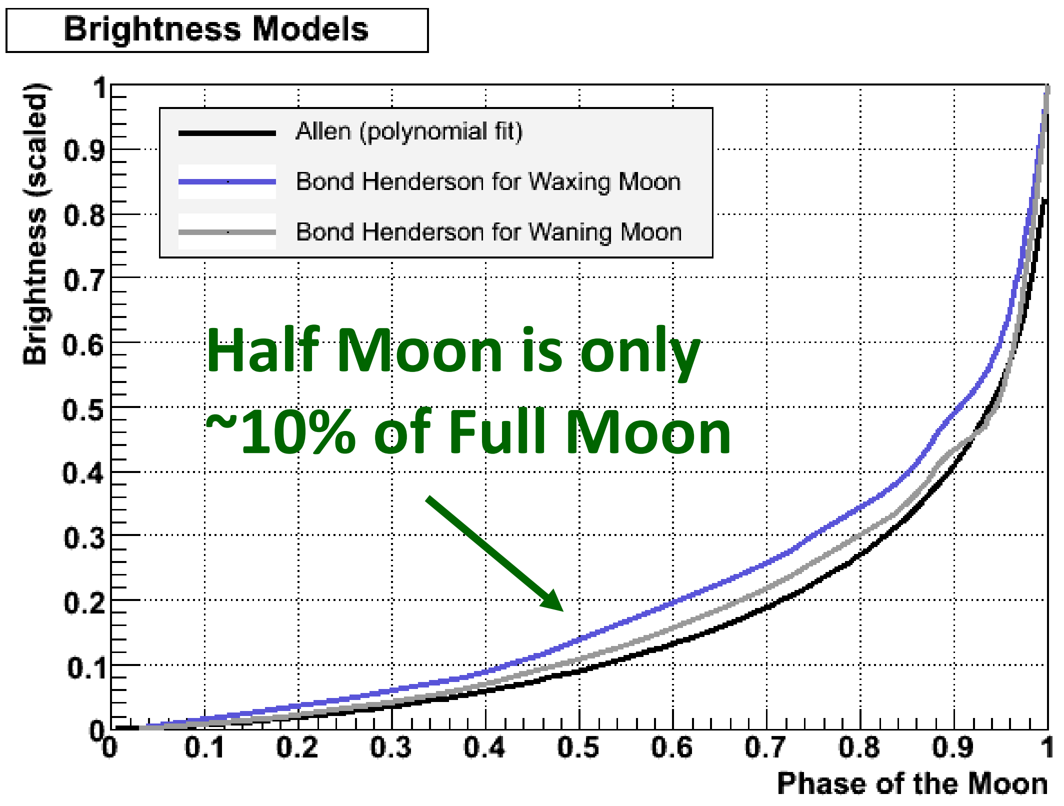
- Understanding of increased background due to moonlight
- Understand impacts on data taken
- Prove the sensitivity of the telescope depending on the background light

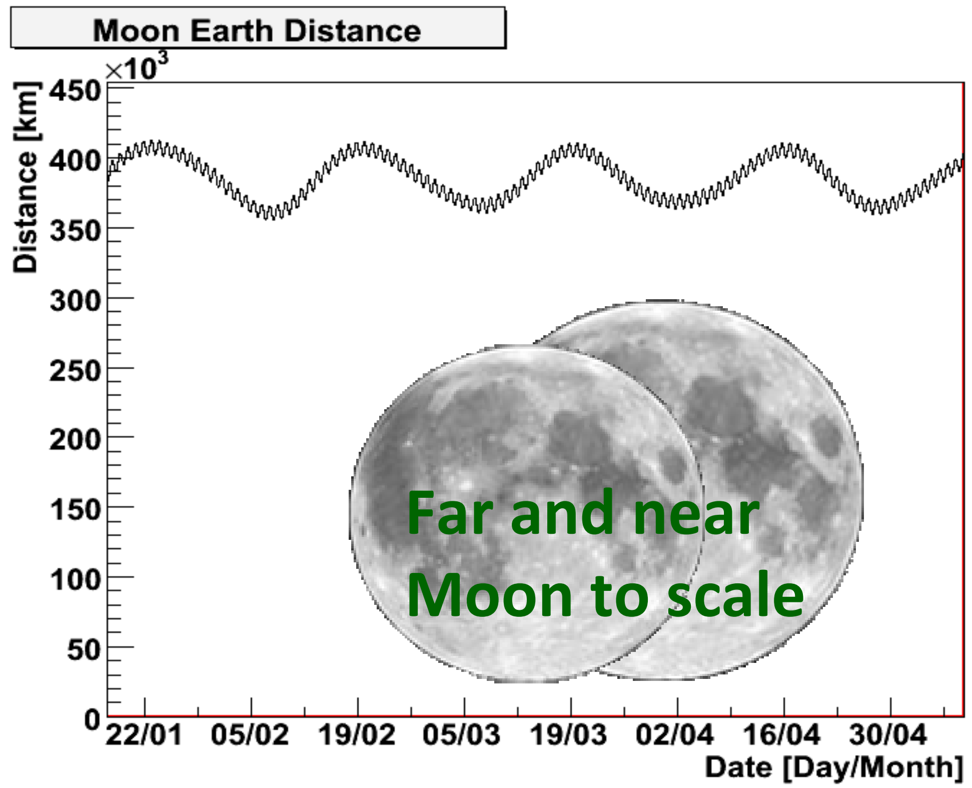




Brightness of the Moon

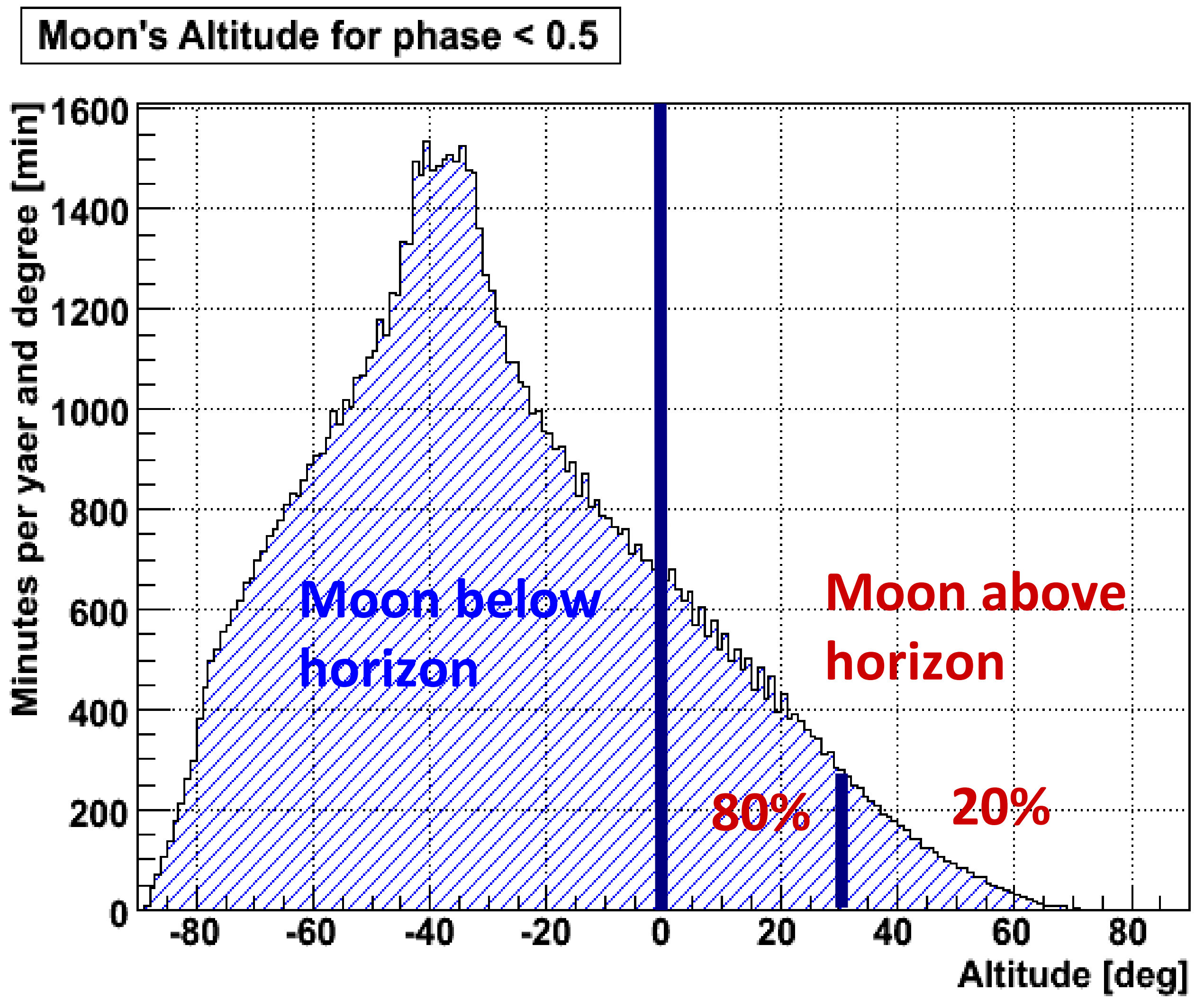
- Moon is gravitationally locked to earth
- Brightness of moonlight is in first order discribed by a polynomial law
- Take also into account distance from earth $(L \sim 1/d^2)$ => 20%
- Further effects mostly brightness close to full moon
- Magnitude from -2.5 to -12.9
- Moon Phase and the altitude during night is correlated
  - No full moon during daytime
  - No new moon when there is night on earth





Observation times

- **1650 h** of darktime observations
- **300 h** of 'moon time' observations with reasonable assumptions
- Half moon is only 10% of the brightness of full moon
- We gain **18%** more observation time
- During this 'moontime', moon is for **80% below 30° altitude** !!!



We have to understand the background light from moon at low altitude !!!

MAGIC data used for the study

- Several hundred hours of moon observations per year with MAGIC
- Crab Nebula (galactic) and Mrk 421 (extragalactic) data from 2007-2008 has been analyzed

Analyzed Data	Crab Nebula	Mrk 421
Moon data from Feb 07 - until May 08 (moon above horizon, source Zd < 45°)	38.6h	37.7h
After bad weather and twilight cuts	36.2h	34 h
Direct Currents (DC) (median of all inner pixels, mean value of one minute)	0.8 – 5.7 μA	0.6 – 8.1 μA
Moon Phase	5% - 53% (80%)	13% - 78% (94%)
Separation Angle ρ [Source | Moon]	25° - 130°	30° - 113°
Moon Altitude	up to 55°	up to 65°

Model for Moonlight Estimations

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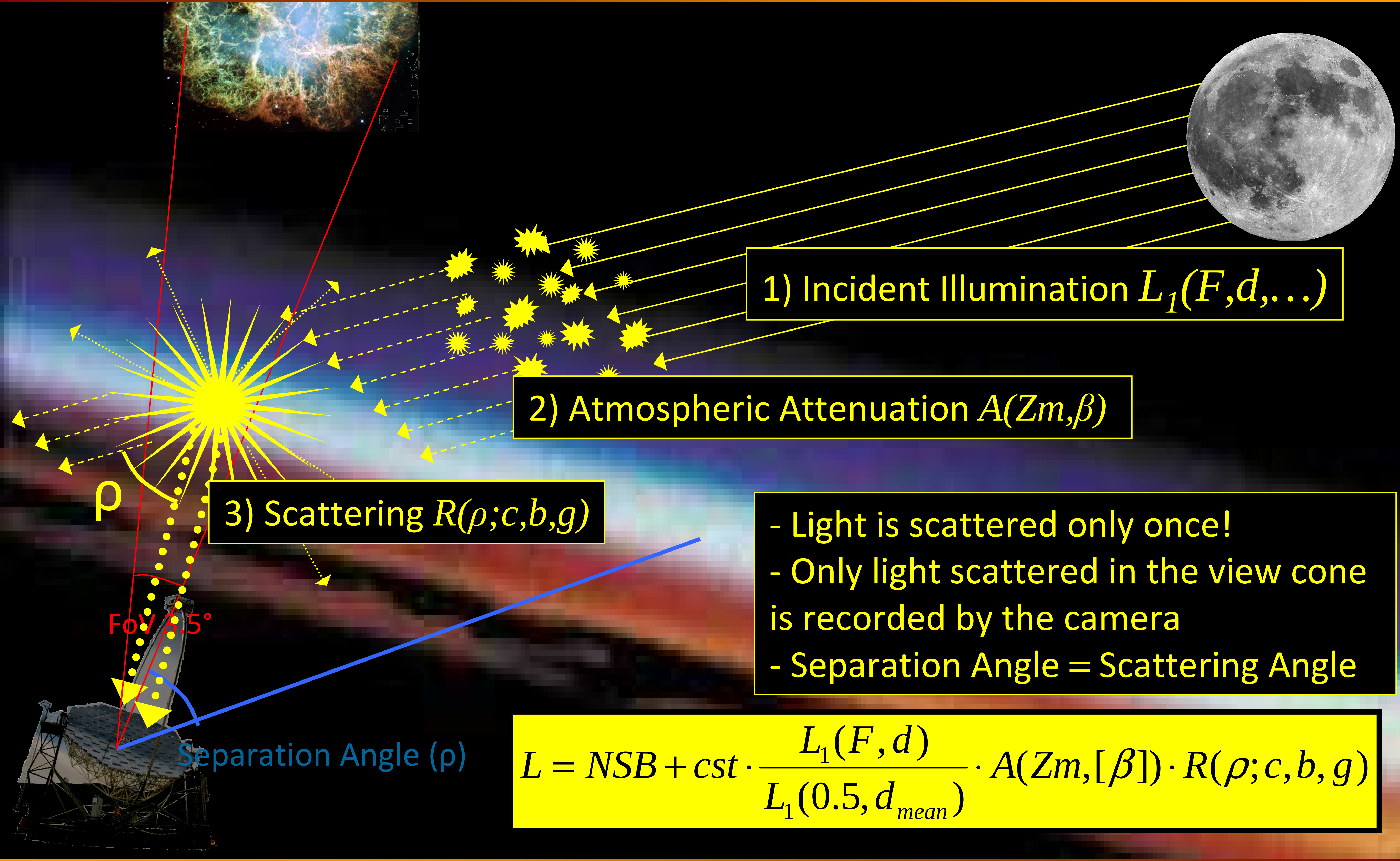


- Light is scattered only once!
- Only light scattered in the view cone is recorded by the camera
- Separation Angle = Scattering Angle

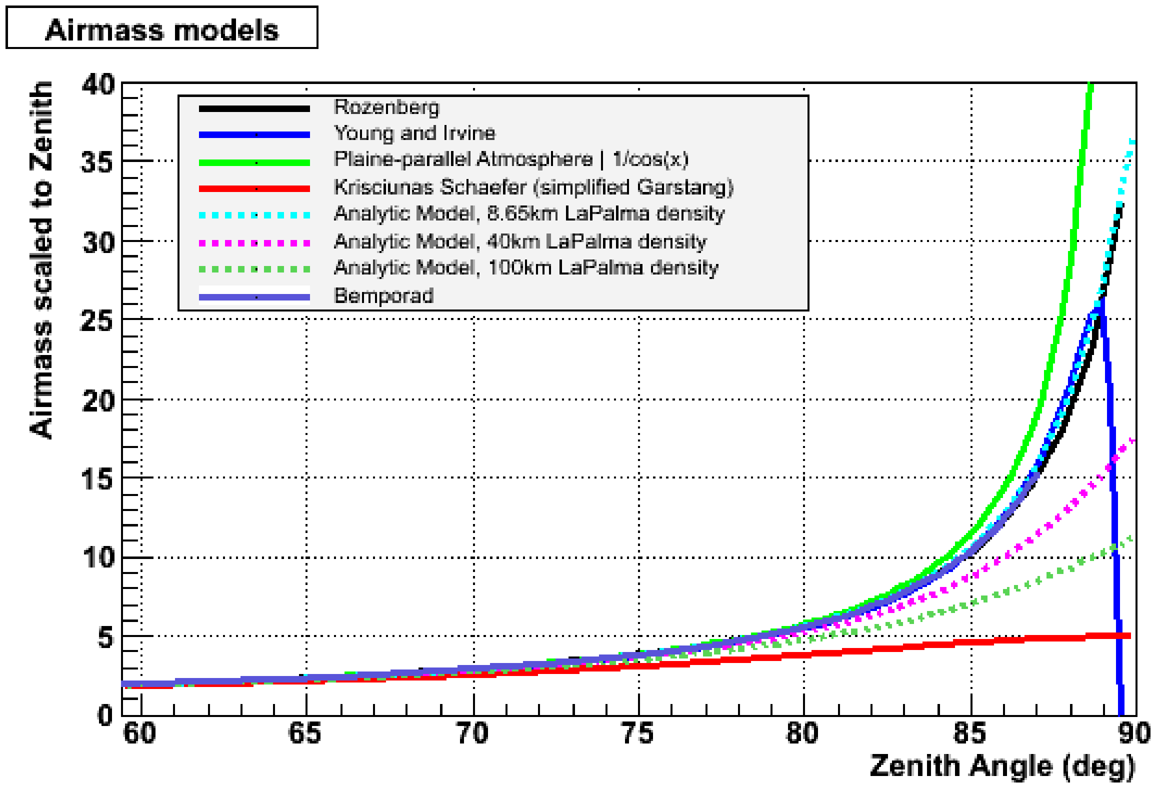
$$L = NSB + cst \cdot \frac{L_1(F,d)}{L_1(0.5, d_{mean})} \cdot A(Zm,[\beta]) \cdot R(\rho;c,b,g)$$

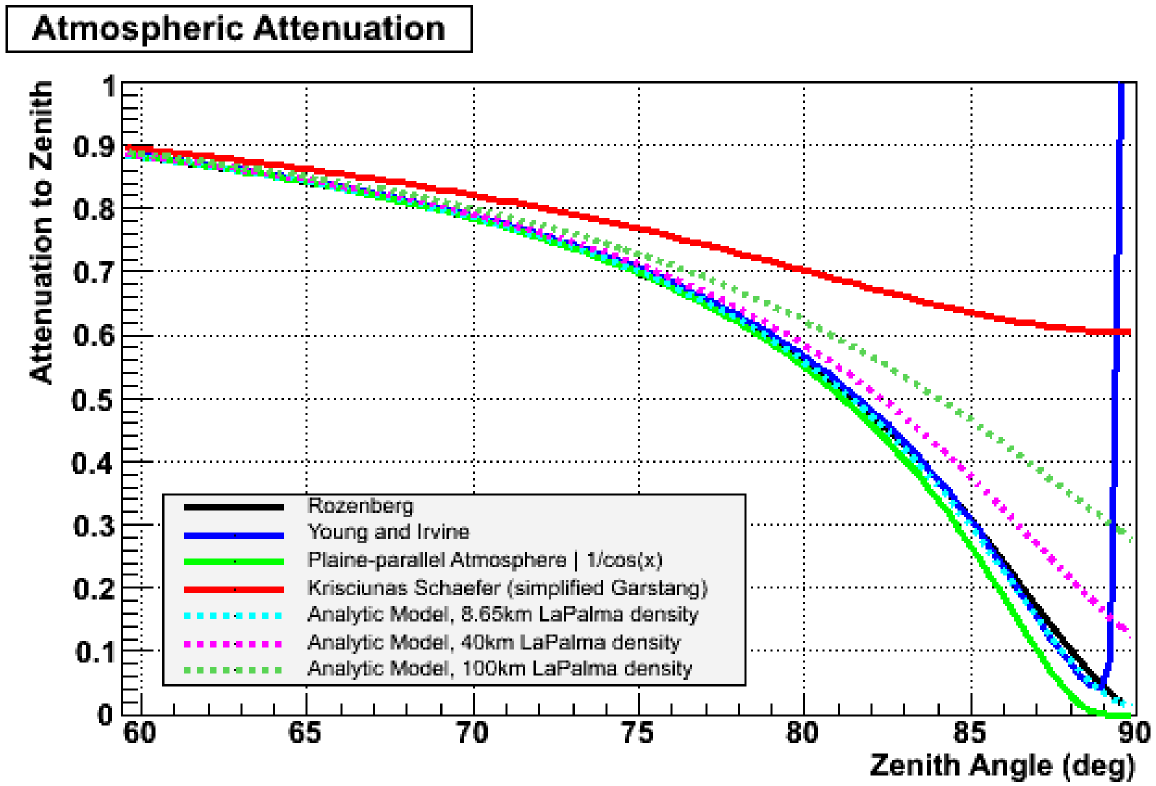
Atmospheric Models

2) Atmospheric Attenuation *A(Zm,β)*

$$A(Zm,\beta) = 10^{-\beta\cdot[\frac{Airmass(Zm)-1}{2.512}]}$$

- *β = Scattering parameter*
- *Zm = Zenith angle moon*
- Well established formulae for atmospheric attenuation (like from Vega observations)
- But have to fine tune atmosphere for moon spectrum and high zenith angles
- Atmospheric attenuation is dominated by Rayleigh scattering
- Rayleigh crosssection σ~ω^4 => Higher Attenuation for PMT-senstitive light





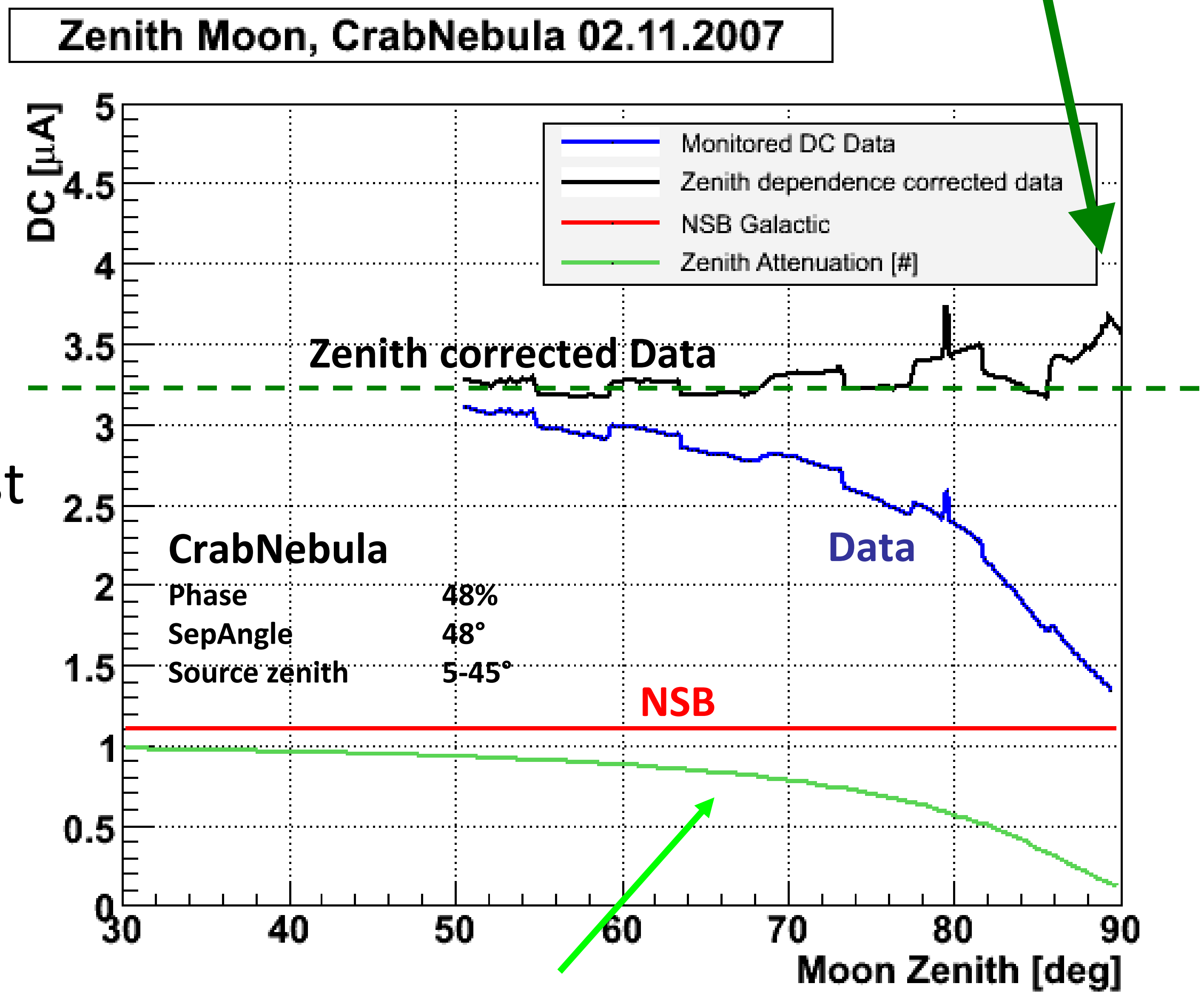
Atmospheric Attenuation

2) Atmospheric Attenuation *A(Zm,β)*

$$A(Zm,\beta) = 10^{-\beta\cdot\left[\frac{Airmass(Zm)-1}{2.512}\right]}$$

- β = *Scattering parameter*
- Zm = *Zenith angle moon*
- The scattering parameter β could be estimated to be 0.145±0.010 from the complete data set
- From **zenith evolution plots** => best Airmass model with denser atmosphere
- Zenith scaled data is supposed to stay constant (dashed line)
- Attenuation almost constant for complete data set

Almost complete Zenith correction up to 90°



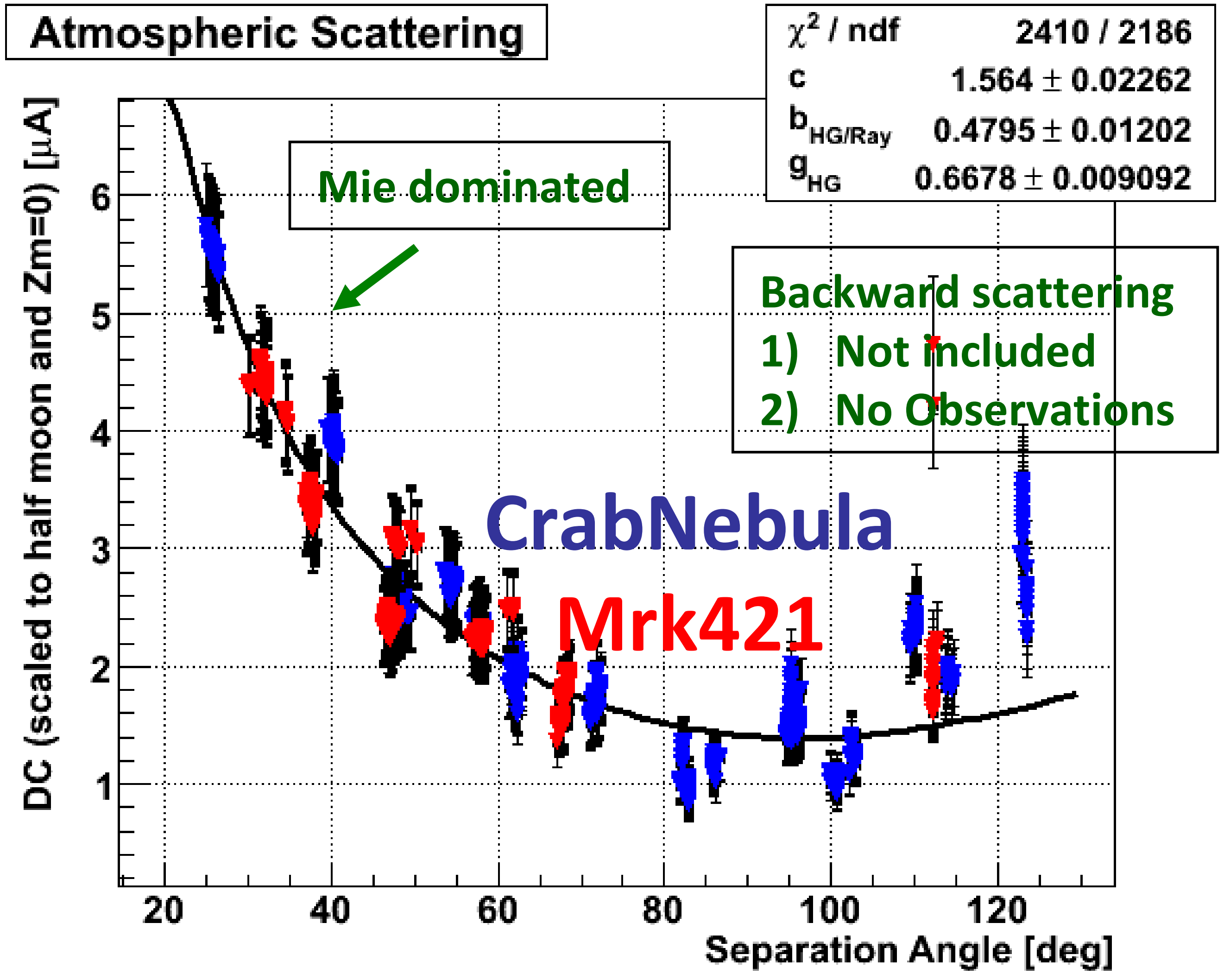
Atmospheric Attenuation [#]

Atmospheric Scattering

3) Scattering $R(\rho;c,b,g)$

$$cst \cdot R = c \cdot [\tfrac{3}{4} \cdot (1+\cos^2 \rho) + b \cdot P_{HG}(\rho, g)]$$

- Scale measured light to
  - Phase
  - Distance to earth
  - Atmospheric Attenuation
  - Correct NSB
- Rayleigh Scattering
- Mie Scattering: approximated by Henyey-Greenstein function P_{HG}
- Only valid between ρ≈20-100°
- For very small separation Angles further scattering effects appear
- DCs are direct proportional to Number of phe⁻ or increase in level of NSB light

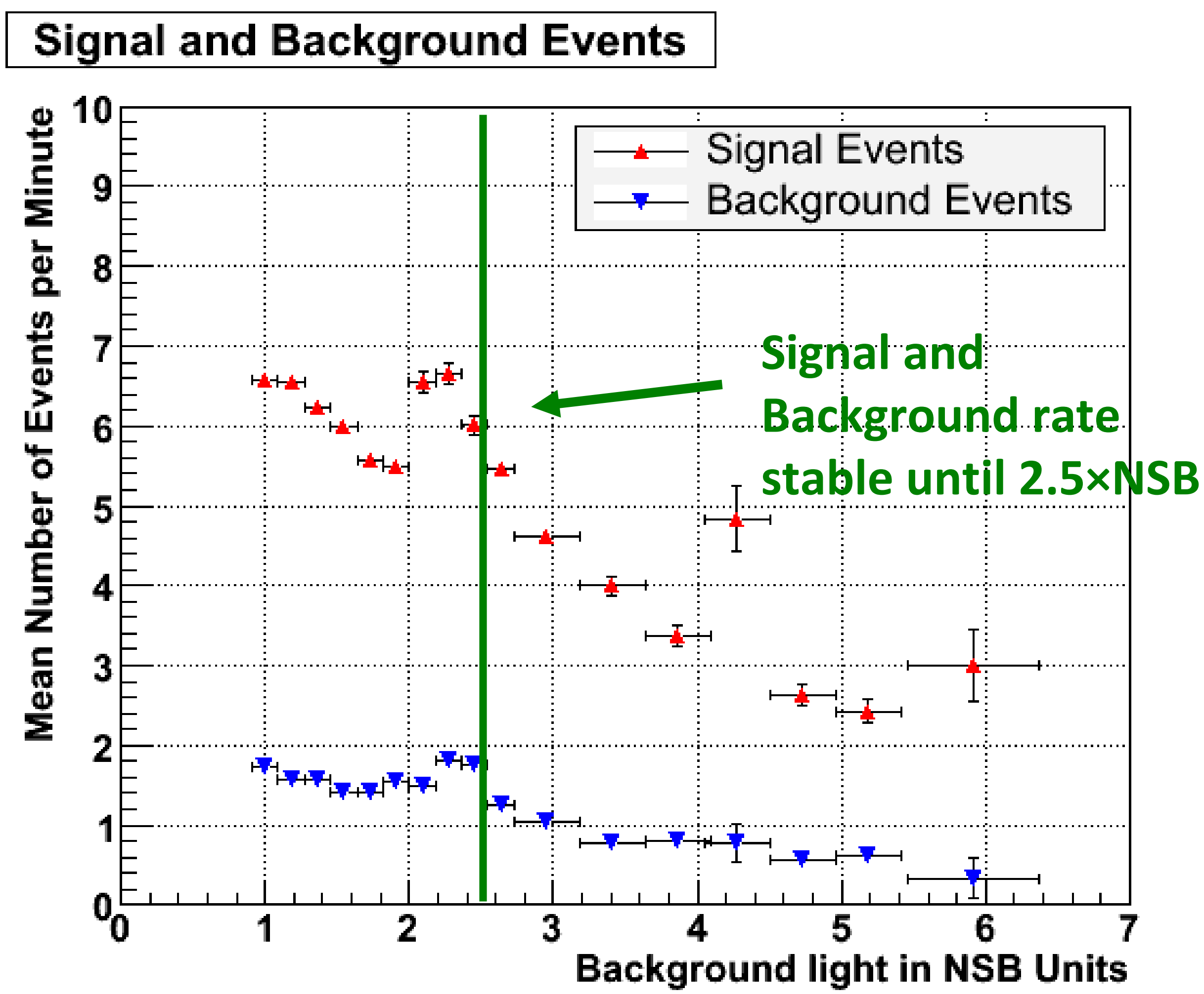


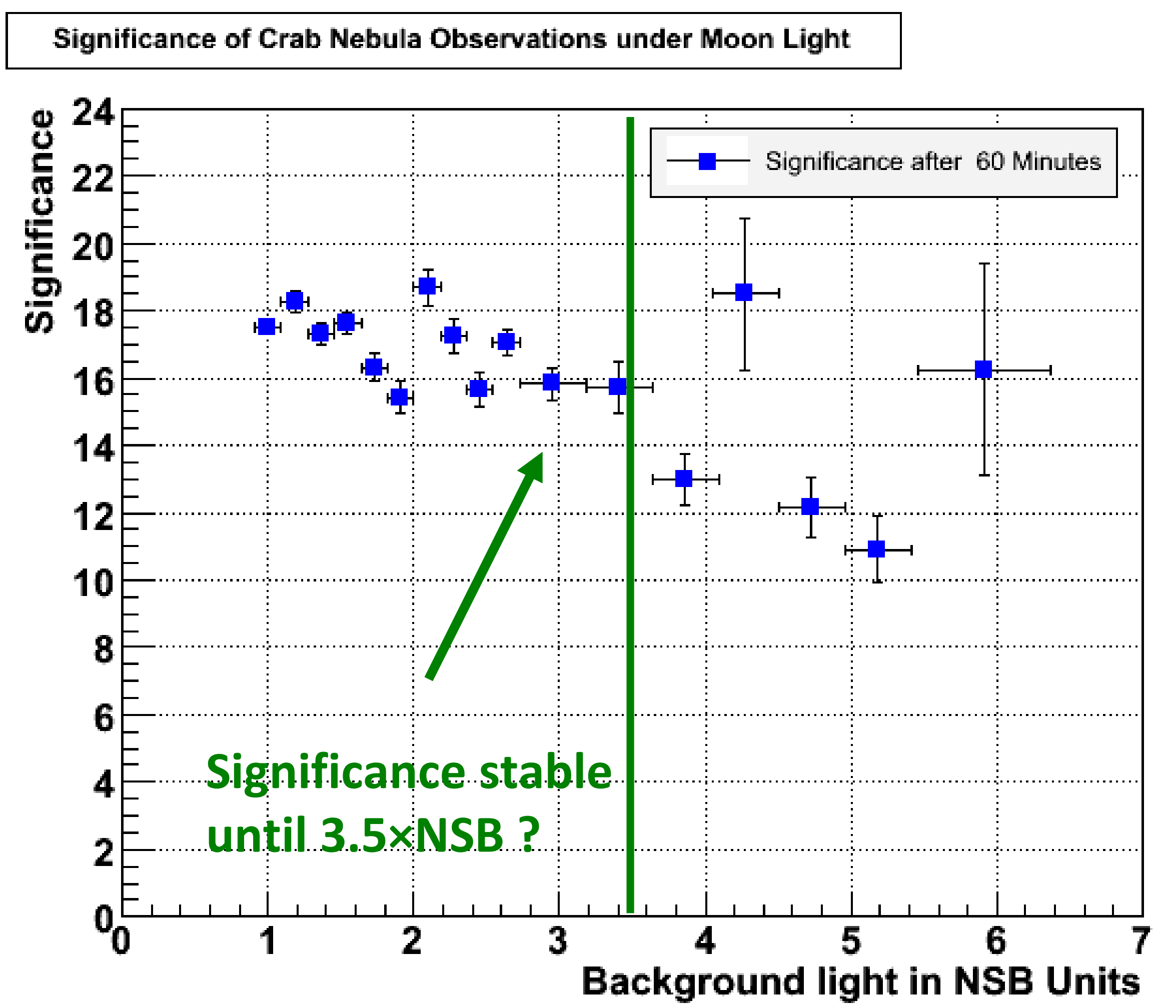
Moon background light for MAGIC I LaPalma

$$L_{DC}(Zm,F,d,\rho) = NSB + 1.56 \cdot [\tfrac{3}{4}(1+\cos^2 \rho) + 0.48 \cdot P_{HG}(\rho, 0.67)] \cdot \frac{L_1(F,d)}{L_1(0.5, d_{mean})} \cdot 10^{-0.145(\frac{Airmass\,40(Zm)-1}{2.512})}$$

Sensitivity of MAGIC

- Over 30h of Crab Nebula observations were analyzed
- MAGIC standard analysis chain was performed
- Same analysis parameters for full dataset, to achieve best comparability
- Energy cut of 300GeV was applied
- Stable signal and background event rate up to 1.5 increased galactic NSB light
- Significance even more stable for higher background conditions





Summary

- 300h additional observation time per year
- A model for estimating the increase of the background light was developed
- The signal and background rate was proved to be stable until 1.5 times the galactic NSB level
- The Sensitivity of the MAGIC telescope seems to be stable for even higher background levels
- Studies of the energy resolution are under investigation
  => Needed for correct flux and spectrum analysis
- Different image cleanings are also under investigation
- Today: 100% Full Moon at 03:37h

MAGIC Major Atmospheric Gamma Imaging Cerenkov Telescope

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LMU

Thank You

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